Durham Third Fork Creek Watershed Management Plan

December 2012

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Stormwater Services

TETRA TECH

Acknowledgements

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Acronyms and Abbreviations

BMP	best management practice
BOD	biochemical oxygen demand
BSD	Better Site Design
CAPP	Critical Area Protection Plan
CIP	capital improvements program
DO	dissolved oxygen
DWQ	Division of Water Quality (North Carolina)
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GIS	geographic information system
HSG	hydrologic soil group
JFLSLAT	Jordan/Falls Lake Stormwater Load Accounting Tool
LA	load allocation
LID	low impact development
MOU	memorandum of understanding
MS4	municipal separate storm sewer system
NCBI	North Carolina Biotic Index
NCCU	North Carolina Central University
NPDES	National Pollutant Discharge Elimination System
POTW	publicly owned treatment works
RAMP	Riparian Area Management Plan
RGD	Reference Guide for Development
SCM	stormwater control measure
SCR	stream corridor restoration
SSO	Sanitary Sewer Overflow
SWMM	Storm Water Management Model
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
UDO	unified development ordinance
WLA	wasteload allocation
WMP	watershed management plan
WMIP	watershed management improvement plan
WQRP	Water Quality Recovery Plan

Glossary

assessment	an evaluation to determine the importance, size, or value
Best Management Practice (BMP)	schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants to waters of the United States; see SCM
Better Site Design (BSD)	a collection of site planning, design, and development strategies that help reduce adverse impacts to the natural environment by recreating, to a certain extent, the original hydrology and plant community of the predevelopment site
biochemical oxygen demand (BOD)	measurement of the amount of oxygen used in the decomposition of organic material, over a specified time period (usually 5 days) in a wastewater or stormwater sample
buffer	something that lessens or absorbs negative effects; see riparian buffer
catch basin	part of the stormwater drainage system that temporarily holds runoff from a specific area (usually a concrete box with a grate where a storm drain empties into the sewer), a catch basin may be used to catch large items that might block the flow in the stormwater sewer
concentrated flow	runoff that accumulates or converges into well-defined channels
diffuse flow	surface runoff flow that is spread out and slowed down to help prevent erosion and protect water quality
discharge	volume rate of stormwater or wastewater flow
illicit discharge	a discharge to a stormwater drainage system that contains anything not specifically allowed by an NPDES permit (whether direct or indirect)
dissolved oxygen (DO)	the amount of oxygen freely available in a body of water – dissolved oxygen is important for a balanced aquatic ecosystem
drainage system (stormwater)	a system of natural and manmade drains, pipes, ditches, and waterways (such as creeks, streams, rivers, wetlands, ponds, and lakes) that collect and carry stormwater—drainage systems can be owned publically or privately

easement	a legal agreement that gives a right to a person or group to make limited use of another's property (examples include having a road on another's property to reach your own or a utility easement where pipe or power lines run through a property)
erosion	a process where water wears away soil and dirt from the land carrying it to water
evaporation	the process where the heat from the sun causes liquid water to become water vapor
evapotranspiration	a combination of evaporation and transpiration
flood / flooding	when a normally dry area becomes covered in water or another liquid
floodplain	an area likely to be covered by rising water (can be outside a FEMA mapped floodplain); also known as flood prone area
floodplain: 100 year	a flood that has a 1 percent chance of occurring in any year
floodplain: 500 year	a flood that has a 0.2 percent chance of occurring in any year
floodway	according to FEMA: where floodwaters are likely to be deepest and fastest, the area of the floodplain that should be kept free of obstructions to allow floodwaters to move downstream
filter	a porous media used for removing impurities or solids from stormwater or wastewater
geographic information system (GIS)	a system used to capture, store, analyze, and display data linked to geographic locations
groundwater	water that filters into the soil and either flows to an aquifer or returns to surface waters; can be shallow or deep
impervious surface	a surface that does not allow water to soak in, usually hard; examples: roofs, roads, and parking lots
infrastructure	the basic physical and organizational structures and facilities (e.g., buildings, roads, utilities) needed for the operation of a society
infiltration	the slow seeping of rain water into the soil
low impact development (LID)	a land planning and engineering design approach to managing stormwater runoff that emphasizes conservation and use of on-site natural features to protect water quality
management, stormwater	controlling the amount and content of stormwater

municipal separate storm sewer system (MS4)	a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) designed or used for collecting or conveying stormwater, and neither includes wastewater nor is connected to a publicly owned treatment works (POTW)
non-point source	water pollution affecting a water body that originates from many, diffuse sources and is difficult to identify and prevent
non-structural control	source-control programs, policies, techniques, etc., that reduce the amount of stormwater pollutants in stormwater runoff by primarily seeking to change human behavior
nutrients	regarded as a pollutant in stormwater runoff; means a chemical element or compound, such as nitrogen or phosphorus that is essential to and promotes the development of organisms
peak flow	maximum volume rate of runoff during a storm event
pervious surface	a surface that allows water to soak in; examples: planted area of ground, forested areas
pollutant/pollution	generally, something that damages or contaminates air, water, or soil
reservoir	a man-made lake used to store water for uses such as a drinking water supply
riparian	an area next to the banks of streams, rivers, lakes, or other bodies of water
riparian buffer	an area with plants and trees next to a body of water that helps protect water quality by filtering pollutants from runoff
runoff	rain or snow melt that does not filter into the soil but instead flows into nearby drains or bodies of water
sanitary sewer	the sewer system that takes used water from sinks, showers, and toilets to the wastewater treatment plant; in Durham the stormwater sewer is separate from the sanitary sewer; also can include waste from commercial and industrial operations
sediment	material worn away from the landscape (such as soil and bits of rock) by water, wind, or ice
screening	the evaluation of a group using a methodical survey to assess suitability for a particular purpose

storm drain	an opening to the stormwater sewer that moves rain or melted snow that does not soak into the ground to a nearby stream, river, or lake
stormwater	water that flows over the land after it rains or snow melts
stormwater control measure (SCM)	any structural or nonstructural strategy, practice, technology, process, program, or other method intended to control or reduce stormwater runoff and associated pollutants, or to induce or control the infiltration or groundwater recharge of stormwater or to eliminate illicit or illegal non-stormwater discharges into stormwater conveyances; see BMP
stormwater drainage system	infrastructure of curbs/gutters, catch basins, manholes, culverts, ponds, etc. used to collect and convey stormwater to its point of discharge; can include SCM's
stream channel	a long, narrow low area a stream usually flows through; includes the bed of the stream and its banks
stream corridor restoration (SCR)	actions and measures designed to enable stream corridors, both the stream channel and adjoining riparian area, to recover dynamic equilibrium and function at a self-sustaining level
structural control	facilities that reduce the quantity or improve the quality of stormwater at or near its source, commonly through filtration, infiltration, and detention. Examples: swales, buffer strips, wetlands, wet/dry ponds, bioretention, permeable pavement
sustainable	conserving an ecological balance by avoiding the depletion of natural resources
total maximum daily load (TMDL)	sum of the individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background under the federal Clean Water Act
total suspended solids (TSS)	measured of combined settleable and non-settleable solids in stormwater and wastewater
toxic	able to cause injury or even death usually by means of a poisonous chemical
transpiration	a process where water vapor is released from a living organism such as through the leaves of a plant or the pores of an animal
unified development ordinance (UDO)	a set of regulations that consolidates most of the requirements that apply to development from both the City of Durham and Durham County

velocity	how fast water flows in a given direction during a specified time
vegetation	plants; trees, shrubs, and grass
wastewater	any water that has been adversely affected in quality by anthropogenic influence; often refers to domestic or industrial waste streams
water body	an accumulation of water such as a river, lake, stream, or ocean
watershed	land areas and their network of creeks that convey stormwater runoff to a common body of water
waterway	navigable body of water such as a river, channel, or canal

Introduction

The City of Durham (hereafter referred to as the "City") is working to be the leading city in providing an excellent and sustainable quality of life (Durham Strategic Plan, 2012 annual report). Consequently the mission of City staff is to provide quality services to make Durham a great place to live, work, and play. For Durham's Stormwater Services Division, this means managing urban stormwater (in other words, water from rain storms) to restore and protect the City's streams, ponds and lakes. Stormwater management is most effective when viewed in the watershed context—watersheds are land areas and their network of creeks that convey stormwater runoff to a common body of water.

Figure 1. Third Fork Creek Watershed Headwaters in Downtown Durham

In 2007, the City launched a watershed management planning process to proactively address changes the City is making to comply with water quality regulations, to improve the health of the streams draining the City, and create value for neighborhoods in the City's watersheds. As a part of that process, the City is finalizing a watershed management plan (WMP) for Northeast Creek and Crooked Creek and has completed one for Ellerbe Creek. This WMP was developed for the Third Fork Creek watershed located in the southern part of Durham County.

Figure 2. American Tobacco Trail In Watershed Headwaters

The Third Fork Creek WMP will primarily support these three goals of the City's Strategic Plan:

Strategic Plan Goal 3: Thriving livable neighborhoods

Strategic Plan Goal 4: Well-managed city

Strategic Plan Goal 5: Stewardship of the City's physical assets

The Third Fork Creek watershed covers an area of 16.6 square miles. As Figures 1, 2 and 3 show, the watershed includes a large portion of the older and highly developed downtown section of the City. It flows through the heart of many Durham neighborhoods like Tuscaloosa-Lakewood, St. Teresa, Forest Hills, Hope Valley Farms, and Woodcroft, down to New Hope Creek, which flows into Jordan Lake. Figure 3 shows the location of these neighborhoods. The northern edge or boundary of the watershed lies in downtown Durham, just north of the Durham Freeway (NC 147), and the southern edge or boundary is close to Interstate 40.

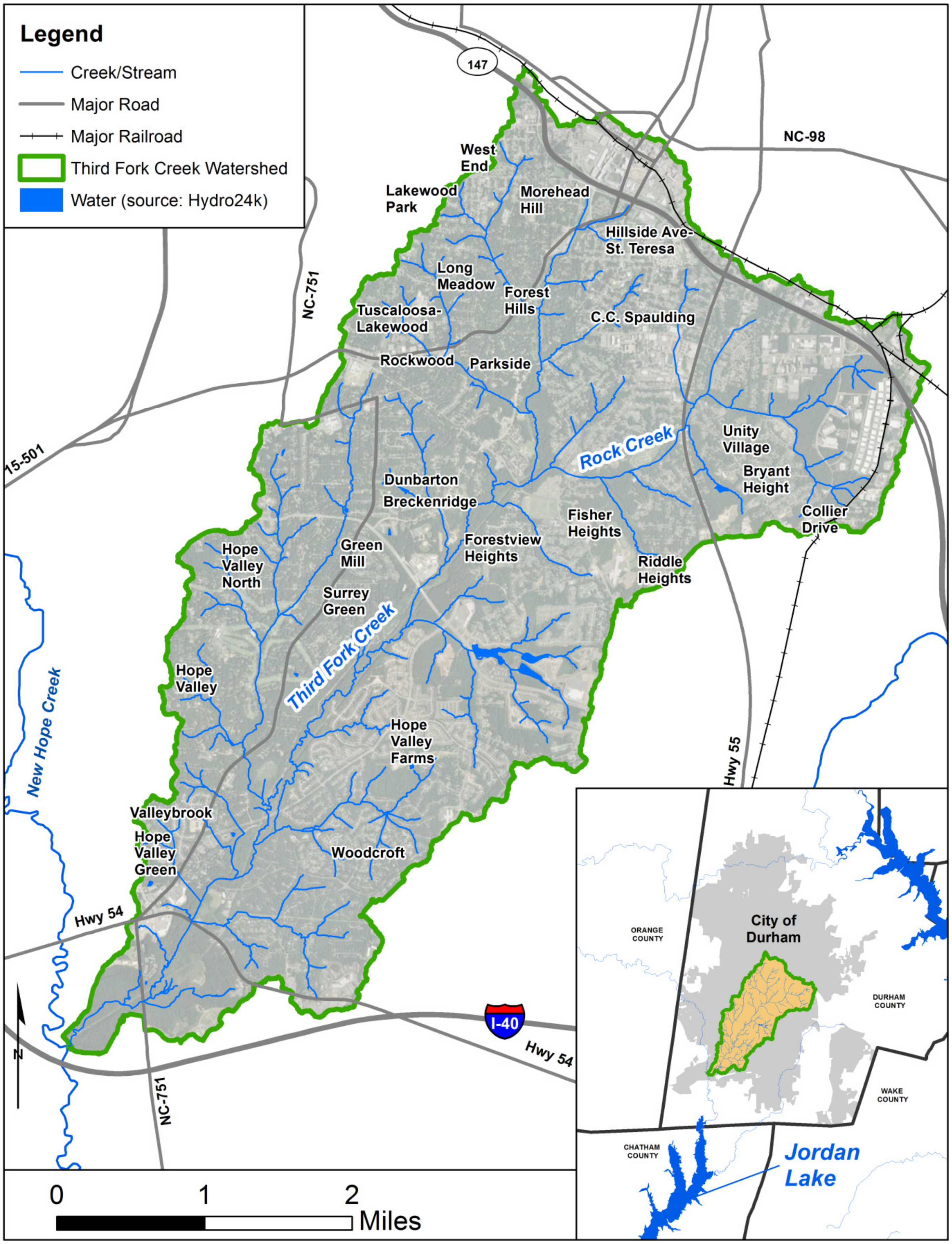

Figure 3. Third Fork Creek Watershed Located in Southern Durham

Why Is the Watershed Management Plan Needed?

The NC Division of Water Quality (DWQ) has determined that Third Fork Creek is not meeting state water quality standards due to high turbidity (muddy water), low dissolved oxygen (impacting the fish and other life in the stream that require oxygen to survive), elevated metals, and poor biological conditions (habitat and health of fish and other aquatic organisms).

DWQ findings also indicate that pollution from the Upper New Hope Creek basin which includes Third Fork Creek is contributing to poor water quality in Jordan Lake, leading to new regulatory requirements for nitrogen and phosphorus reduction. The Jordan Lake Nutrient Management Strategy was enacted in 2009 and provided a regulatory framework for municipalities to reduce nitrogen and phosphorus from a variety of sources, including reductions from new development and existing development. Nitrogen and phosphorus are essential nutrients for life. However, too much can lead to algae blooms and fish kills. In addition to nutrients, stormwater that washes over urban and suburban land in the watershed picks up trash, motor oil, grease, lawn care chemicals, dirt, and bacteria carrying these pollutants to the creek. High flows during rainstorms dig out or erode stream banks sending additional sediment downstream. Also, leaking or overflowing sewer pipes and failing septic systems are sources of bacteria and nutrients.

Organization of the Third Fork Creek WMP

The WMP is organized into three volumes:

1. **Volume I – Executive Summary**. This brief document describes the approach for developing the WMP, key findings of the assessment of watershed conditions, existing efforts that provide a current base or foundation for watershed management, project prioritization criteria, high-priority watershed improvement projects (see Table 1 and Figure 6) and actions recommended, and the associated costs and benefits of implementing the WMP.

2. **Volume II – Watershed Management Plan**. The main report summarizes the methods for developing the WMP; describes the character of the watershed (such as current land use); discusses water quality issues and the primary forces negatively affecting water quality; states the goals and objectives of the WMP; highlights existing management efforts in the watershed; shows watershed improvement opportunities; and describes a plan for implementing the high-priority projects and actions.

3. **Volume III – Technical Appendices**. A series of memoranda and reports prepared throughout the project are included in Volume III. They describe in more detail the technical approaches used and results of the analyses.

Approach for Developing the WMP

The City established a Coordination Team made up of staff from multiple City departments to develop the Third Fork Creek WMP. A GIS-based desktop screening was performed using a variety of data (including parcel information, aerial photography, sanitary and storm sewer locations, topographic and hydrographic data, and floodway locations) to narrow the focus to the land parcels with the best potential for success (see Appendix C, Third Fork Creek BMP Screening Summary). The Coordination Team and interested citizens walked the Third Fork Creek watershed, taking measurements and documenting conditions, and especially noting problem areas and their causes. The Team identified candidate sites for potential in-stream restoration, restoration of riparian buffers (streamside vegetation that filters runoff before it enters the creek), and preservation of critical natural areas along streams. Studies of watershed areas helped the Team evaluate whether existing structural stormwater control measures (SCMs) such as detention ponds, could be modified to improve water quality in the watershed, and to identify parcels of land where new structural SCMs could be placed on existing built-upon properties to treat existing developed areas. The field work also helped to identify areas where non-structural SCMs such as changes in the rate and timing of fertilizer application, enhanced street sweeping, and installation of raingardens could better protect water quality in Third Fork Creek.

Next a computer-based watershed water quality model (SWMM) was set up that simulates Third Fork Creek and its contributing watershed. The model allowed the City to better understand the relationships between land use and land cover, stormwater control measures, the resulting stormwater runoff volume and quality that can impact Third Fork Creek. The model included a simulation of existing SCMs to gauge performance of managing runoff volume and pollutant washoff (i.e. of nitrogen, phosphorus, sediment, metals, and bacteria). The modeling results helped to identify the areas within the watershed that generate the highest amounts of the pollutants of concern.

The combination of results from the existing data review, Geographic Information Systems (GIS) analyses, stream studies, upland studies, and watershed water quality modeling were used to identify and prioritize areas most in need of management in the Third Fork Creek watershed. Opportunities for upgrading existing or constructing new stormwater SCMs were evaluated and ranked, as were potential opportunities for stream and buffer restoration projects. Additionally, existing undeveloped lands determined to be important for water quality were identified and prioritized within a Critical Area Protection Plan (CAPP). See the WMP Section 5 and the technical appendices for more details.

Existing City programs, codes, and practices were evaluated to identify opportunities to enhance water quality protection. In addition to the citizens' assistance in the field surveys, public workshops were held at key milestones during the project to hear concerns and get input from property owners, environmental groups, and the general public.

The Coordination Team used a combination of field data and modeling to determine what type of projects are needed to restore Third Fork Creek and where they should be located.

The City selected five SCM and five stream restoration projects to develop preliminary and concept designs for implementation. Additionally, an existing, developed City property was chosen as a demonstration site for potential application of Better Site Design (BSD)/Low Impact Development (LID) practices.

Watershed Assessment

For the watershed assessment portion of the WMP, information was collected and evaluated on current conditions within the Third Fork Creek watershed to develop an understanding of overall health and critical management areas. Three components of this assessment included:

(1) Initial review and preliminary characterization of existing data from the City and other sources.

(2) Field assessment studies including stream channel, areas adjacent to the streams, and upland areas that drain to the creek.

(3) Watershed modeling to aid in understanding existing and future watershed conditions (particularly pollutant loading and stormwater volume impacts), and the impact of new and existing structural stormwater control measures.

Based on the analysis, a number of important characteristics of the Third Fork Creek watershed were identified:

- **Soils:** Third Fork Creek lies entirely within the Triassic Basin geologic region. Soils in this area tend to be fine-grained with high clay content and low permeability. Water infiltrates slowly resulting in higher volumes of run-off compared to more permeable soils.
- **Land Use:** The watershed's land use and land cover greatly influence the volume and velocity of stormwater runoff as well as the composition and concentration of pollutants. A large percentage of land within the watershed has been converted from forest to developed land or road networks over the past 50 years. Approximately 48 percent of the Third Fork Creek watershed is devoted to residential uses, half of which are considered low density. Nearly 8 percent of the watershed is classified as commercial or industrial land uses, most of which occur in Rock Creek and headwaters of Third Fork Creek.
- **Specific Sources of Watershed Impacts:** The Third Fork Creek watershed has a number of issues that affect water quality and aquatic habitat which are similar to other watersheds that experienced significant suburban and urban development prior to more strict water quality protection standards. The following sources of watershed impacts have been identified:
  - Hard surfaces encourage direct runoff to streams rather than allowing rainwater to slowly percolate or infiltrate through the soil. These impervious surfaces include buildings, parking lots, roads, sidewalks, and other features. The total imperviousness for the watershed is approximately 25 percent.
  - A number of factors were observed in the field that are impacting stream health, including streambank erosion, utility and infrastructure crossings, major trash/debris dumping locations, poor buffer/floodplain condition such as lack of vegetation, stormwater outfalls, and stream channel modifications. Stream reaches were assigned overall assessment scores based on their current condition.
  - Alterations in stream channel form and dynamics are often a result of upstream watershed development and changes in land use and land cover. Evidence of these alterations is prolific

throughout the watershed and is typically characterized by active stream channel processes that result in changes to the stream banks, vegetation, and stream bottom. Specifically, the Team identified:

- Downward erosion that deepens the stream (incision) was present in 15 percent of stream segments.
- Stream widening and movement of large amounts of dirt and rock (mass wasting) was observed in 44 percent and 29 percent of stream segments assessed, respectively.
- Older and higher density development (i.e., the portion of the watershed that includes Forest Hills, Tuscaloosa-Lakewood, Hillside Ave-St. Teresa, Parkside and Morehead Hill) has contributed to stream channel damage and degradation along the upper portion of Third Fork Creek. Older and higher density development has also contributed to damage and degradation along the Rock Creek (RC) mainstem and the upper portion of the unnamed tributary west and parallel to NC-751.

- The Third Fork Creek watershed water quality simulation model was used to estimate the current annual pollution loading rate. Currently, over 16 tons (36,200 lbs) per year of Total Nitrogen, 1.8 tons (3,950 lbs) per year of Total Phosphorus, and 397 tons per year of sediment (the equivalent to over 30 dump truck loads) are estimated to be entering Jordan Lake. State regulations require that the City reduce loading from existing development to meet water quality standards. In the coming years, the City will need to carry out new projects and programs that can reduce existing pollutant loading to help meet state goals: Total Nitrogen load by 35 percent and Total Phosphorus load by 5 percent (as measured from years 1997 to 2001 as a baseline), and sediment load by 53 percent (as measured from years 2000 to 2003 as a baseline).
- The City has recently adopted stormwater management regulations for new development that limit the amount of allowable runoff to reduce annual pollutant loads. Although new development in the watershed is required to follow these regulations, predictions of future conditions using the watershed model estimate that annual pollutant loading rates will be higher than current rates. Offset mitigation is expected to take place given the projected development densities. As a result, structural SCMs do not completely mitigate the increase in pollutant loads, since SCM selection in the model was optimized to reduce post-development Total Nitrogen loading rates by 40 percent rather than return the sites to pre-developed loading rates. Under the Future Scenario with SCMs treating new development, the model estimated that Total Nitrogen will be 17 tons per year, Total Phosphorus will be approximately 2 tons per year, and sediment will be 406 tons per year. This underscores the importance and urgency of building SCMs to treat existing development where the pollutant loading is high to complement the SCMs being built in new developments.
- Stream segments with ‘optimal’ in-stream habitat, vegetated and intact buffers, minimal erosion, and a well-connected floodplain were identified (Figure 4). These areas are recommended for protection.

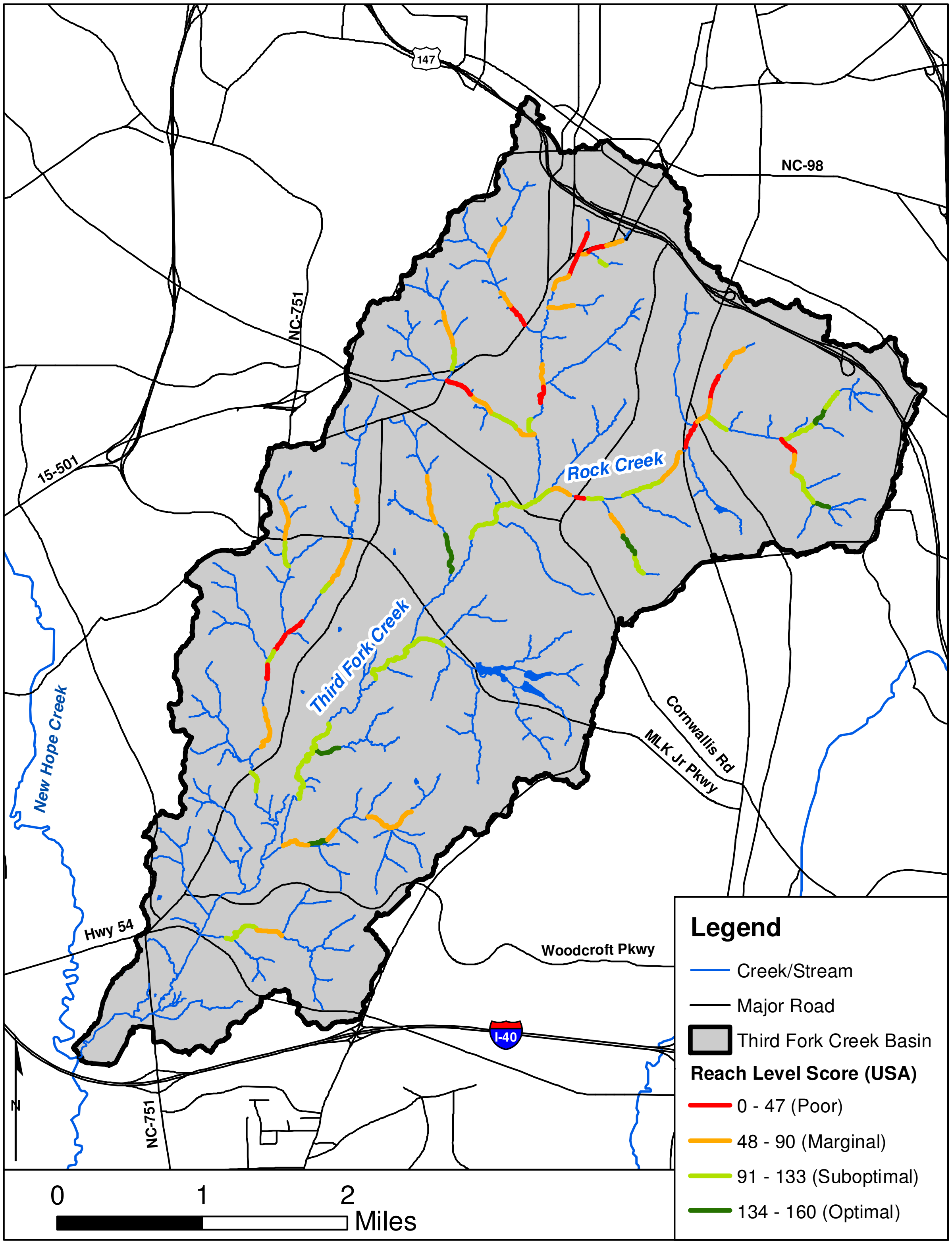

Figure 4. Scores for Overall Stream Channel Condition

Management Need Areas

To simplify the overall evaluation and provide results that can be linked more directly to the WMP management objectives, a shorter subset of the assessment indicators (aquatic habitat, channel stability, and simulated water quality) was used to identify areas of the watershed most in need of management practices. Scoring methods were developed that summarize the watershed impacts from multiple indicators. The pollutant loading indicators provide measurements of impacts of loading to a stream. Indicators like aquatic habitat provide measurements of instream impacts. Two separate scores were developed: 1) Subwatershed Loading Composite and 2) Instream Composite. The 60 subwatersheds used in the SWMM model were scored by each individual indicator, and these individual scores were aggregated to calculate the two composite scores. The highest scores were assigned based on values that best represent achievement of the WMP goals.

A step-by-step process was used to identify management need areas that best address watershed impacts. The process resulted in assigning each subwatershed to one of the following management needs categories:

- Stream Corridor Restoration (SCR) Needs: the greatest need relating to instream channel and riparian area habitat impacts. Need SCRs that enhance or restore the stream channel or stream buffer area.
- Stormwater Control Measure (SCM) Needs: the greatest need relating to pollutant loading and hydrology impacts that would support stream restoration. Need SCMs that manage stormwater from existing impervious areas.
- SCR and SCM Needs: subwatersheds identified as having both SCR and SCM needs.
- Fewer Needs

On the basis of the existing impacts and sources of those impacts in the watershed, high-priority management areas and practices were identified. The areas highlighted in Figure 5 are the highest priority areas for restoring stream corridors and reducing the effects from pollution and volume of stormwater runoff.

Existing Management Foundation

A variety of local, state, and federal regulations affect activities in the watershed and form an existing management foundation for improving water quality and habitat conditions. Important ongoing efforts by the City include the following:

- The City's National Pollutant Discharge Elimination System (NPDES) Phase I and Phase II stormwater permitting program requirements since 1994. This includes public education and participation activities about water quality, detection and elimination of illicit discharges, regulation of new development, inspections and maintenance of SCMs, pollution prevention for municipal and industrial facilities, and monitoring.
- Water Supply Overlay standards for protection of the Jordan Lake water supply began in 1984.

- The City's staged implementation of the Jordan Lake Nutrient Management Strategy Rules and associated requirements for new and existing development began in 2009 and was progressively enhanced through changes in the City's Stormwater Performance Standards for New Development in 2010 and 2012.
- The erosion and sedimentation control requirements for development projects began in 1984.
- Other stormwater management performance standards relating to flooding and other impacts began in 1997.

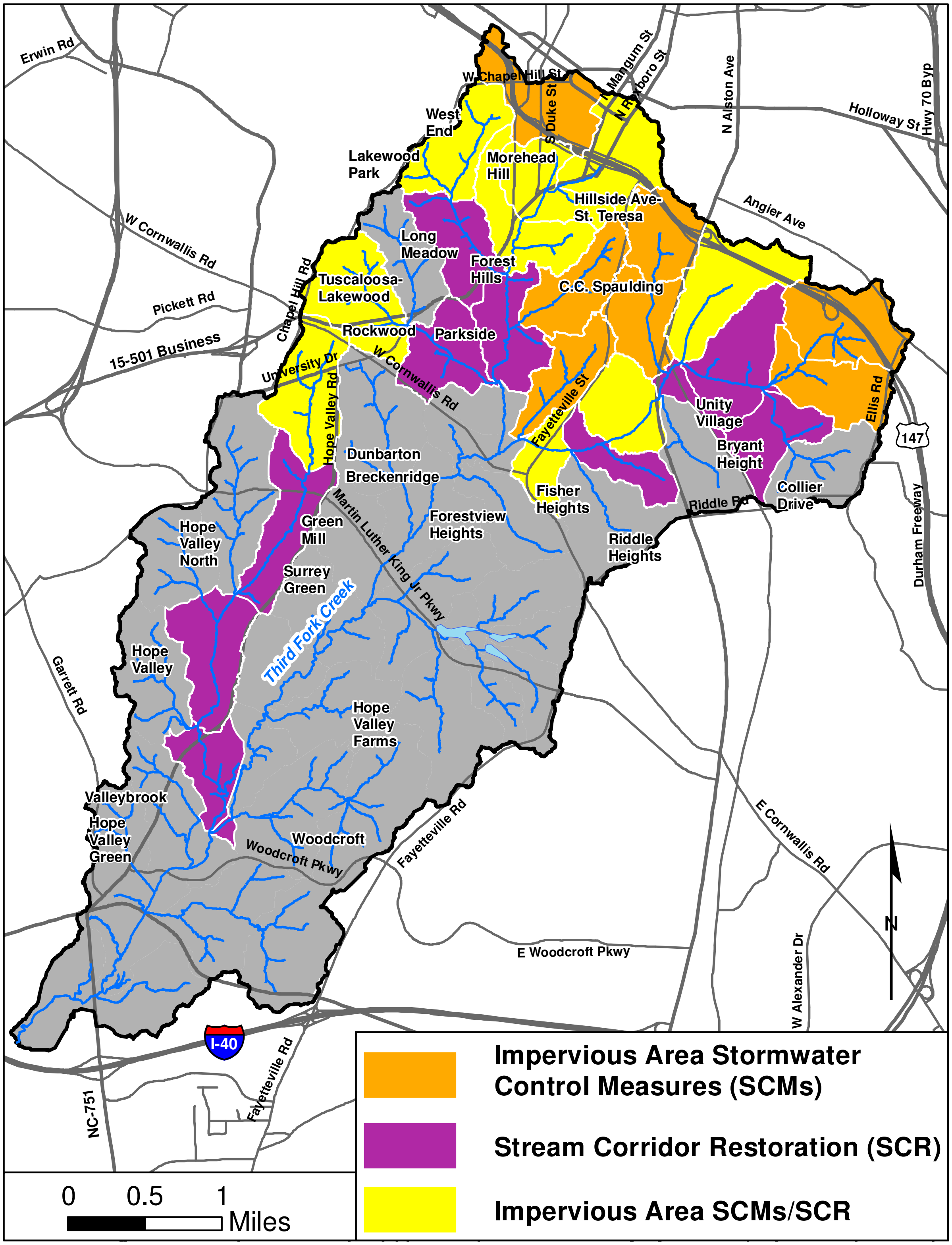

Figure 5. High-Priority Management Areas

Project Prioritization Criteria

Project prioritization is a critical component of a WMP. With more than 300 identified potential projects for watershed improvement and protection a method of evaluation and prioritization was developed to better allocate limited staff time and resources. Evaluation and prioritization of the projects was based on the six criteria listed below:

- **Water Quality Treatment**: prioritizes projects that are most cost-effective for reducing existing pollutant loads of Total Phosphorus, Total Nitrogen, Total Suspended Solids, Fecal Coliform Bacteria, and Copper.
- **Habitat and Biological Integrity**: prioritizes projects that are likely to be the most successful at improving aquatic habitat, increasing the abundance and diversity of aquatic life, and minimizing future risks to aquatic life within the watershed.
- **Streambank and Channel Protection**: prioritizes projects that minimize erosion of streambanks and channels, as measured by the degree that bank and channel stability is maintained or improved by the opportunity.
- **Community Enhancement**: prioritizes projects based on how beneficial they are to the public This category addresses property protection, property owner and neighborhood acceptance, and public education.
- **Implementation Issues**: prioritizes opportunities based on how feasible they are to implement by the City. This category measures the feasibility based on property ownership, land acquisition costs, City program compatibility, and site accessibility.
- **Public Safety and Public Property Considerations**: prioritizes opportunities by the degree to which they directly protect public safety and public property.

High Priority Watershed Improvement Projects

Using the above prioritization criteria the Coordination Team identified the highest scoring projects for a given practice. Projects that provide multiple benefits to the community scored highest. This information was combined with the High Priority Management Areas shown in Figure 5 to select the best projects. The top 15 sites for new SCMs, top 3 sites for retrofit of existing SCMs, top 15 sites for stream restoration and enhancement, and top 15 sites for buffer restoration are listed in Table 1 and locations are displayed in Figure 6. The highest priority opportunities for land to be protected in the Third Fork Creek watershed are also displayed in Table 1 and Figure 6. These include the top 15 keystone sites (critical lands near a large protected area) and top 15 urban gem sites (smaller, high-quality parcels in the watershed's more urbanized areas). The Table lists the estimated cost for each project, including engineering and design, purchase of land, construction, and annual maintenance over 20 years.

Table 1. Recommended High-Priority Sites and Practices

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
Stormwater Control Measures – New				**Total: $3,581,396**
1	005	Wetland	Just east of the Utah St. and Fayetteville St. intersection. Legacy project ID 130.	$350,902
2	010	Wetland	Just east of the University Drive entrance to Hope Valley Elementary School. Legacy project ID 160.	$194,421
3	006	Wet Pond	Western edge of the playing fields of Shepard Middle School near the corner of Elmira Avenue and Dakota Street. Legacy project ID 131.	$363,381
4	004	Bioretention	Median areas within the new City of Durham bus terminal adjacent to impervious areas of bus loading and unloading zones. Legacy project ID 118.	$339,531
5	036	Bioretention	Behind the Phail Wynn, Jr. Student Services Center on Durham Technical Community College, Durham Campus between E Lawson Street and Cooper Street. Legacy project ID A_n_2.	$171,483
6	018	Bioretention	At the eastern edge of Forest Hills Park just downstream and west of the American Tobacco Trail. Legacy project ID 1722.	$190,071
7	039	Wetland	Southwest corner of Hope Valley Elementary School off Dixon Road. Legacy project ID B_n_3.	$185,212
8	030	Wetland	Downhill and southeast of Burton Elementary School located at the corner of Mathison Street and Lakeland Street. Legacy project ID 164a.	$155,994
9	032	Wet Pond	At the northwest corner of Blackwell Street and W. Lakewood Avenue near Forest Hill Heights. Legacy project ID 789a.	$173,977
10	012	Wet Pond	Northwest of WG Pearson Magnet Middle School at the intersection of E. Umstead Street and Merrick Street. Legacy project ID 165.	$217,646
11	007	Rainwater Harvesting	Morehead Elementary School between W. Cobb Street and W. Lakewood Avenue. Legacy project ID 141.	$221,711
12	013	Bioretention	Just south of Durham Freeway (Highway 147) near the Old Tobacco Campus. Behind the array of satellite dishes at the corner of W. Morehead Avenue and Blackwell Street. Legacy project ID 169.	$379,662
13	015	Wetland	A community park that consists of tennis courts, basketball courts, a playground area and associated parking and other facilities. Legacy project ID 182.	$276,547

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
14	017	Bioretention	On NC Central University campus just south of Nelson Street across the street from three older, converted residential buildings. Legacy project ID 204.	$192,856
15	038	Wetland	Southeast corner of Hope Valley Elementary School. Legacy project ID B_n_2.	$168,002
Stormwater Control Measures – Retrofit				**Total: $316,494**
1	051	Wetland Retrofit	Cleared area off of the entrance drive to W.G. Pearson Elementary School near the intersection of Fayetteville Road and E. Cornwallis Road. Legacy project ID 452.	$119,169
2	048	Wetland Retrofit	Open space courtyard area on NC Central University Campus near the corner of E. Lawson Street and Concord Street. Legacy project ID 294.	$96,921
3	046	Detention Retrofit	Southern side of NC Central University Campus Building between building and Formosa Avenue near Concord Street. Legacy project ID 70.	$100,404
Stream Corridor Restoration				**Total: $9,857,160**
1	100	Enhancement Level 1 Stream Restoration	Unnamed tributary of Third Fork Creek flowing through Hope Valley Golf Course from below Surrey Road down to next project. Legacy project ID 233.	$356,929
2	071	Enhancement Level 2 Stream Restoration	Unnamed tributary of Third Fork Creek flowing through Hope Valley Golf Course from above Dover Road approximately 1,700 feet down to the Dover Road crossing. Legacy project ID 142.	$820,378
3	101	Enhancement Level 1 Stream Restoration	Unnamed tributary to Third Fork Creek on the western edge of Forest Hills Park downstream of W. Forest Hills Blvd. for approximately 600 feet. Legacy project ID 234.	$530,085
4	054	Comprehensive Stream Restoration	Unnamed tributary to Third Fork Creek on the western edge of Forest Hills Park upstream of 15-501 Business (University Blvd.) for approximately 1,550 feet. Legacy project ID 103.	$1,099,702
5	085	Enhancement Level 1 Stream Restoration	Third Fork Creek just downstream of S. Roxboro Road down to the western terminus of Red Oak Avenue. Legacy project ID 211.	$636,003
6	084	Enhancement Level 1 Stream Restoration	Third Fork Creek just downstream of the existing stream restoration project to S. Roxboro Road. Legacy project ID 210.	$676,783

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
7	086	Enhancement Level 2 Stream Restoration	Rock Creek from near the western end of Corona Street to near the western end of Chalmers Street for approximately 450 feet. Legacy project ID 213.	$314,556
8	070	Stream Bank Stabilization	Unnamed tributary of Third Fork Creek flowing through Hope Valley Golf Course from Devon Road to Surrey Road. Legacy project ID 140.	$903,066
9	061	Enhancement Level 2 Stream Restoration	Unnamed tributary of Rock Creek running from E. Lawson Street just west of S. Alston Ave (Highway 55) under Dayton Street ending at Truman Street. Legacy project ID 118.	$696,503
10	064	Enhancement Level 1 Stream Restoration	Rock Creek flowing down from S. Alston Avenue to Apex Highway/Highway 55. Legacy project ID 121.	$978,252
11	090	Enhancement Level 2 Stream Restoration	Rock Creek from approximately 300 feet upstream (east) of Fayetteville Street to its crossing under Fayetteville Street. Legacy project ID 217.	$265,673
12	059	Enhancement Level 2 Stream Restoration	Unnamed tributary of Rock Creek running parallel behind the houses north of Hearthside Street near Welch Place. Legacy project ID 116.	$620,672
13	087	Enhancement Level 2 Stream Restoration	Rock Creek from near the western end of Chalmers Street for approximately 875 feet to Elmira Avenue. Legacy project ID 214.	$592,861
14	080	Enhancement Level 2 Stream Restoration	Third Fork Creek headwaters flowing parallel to 15-501 Business (W. Lakewood Avenue) between 15-501 Business and Hillside Avenue flowing under South Street. Legacy project ID 206.	$517,591
15	098	Enhancement Level 2 Stream Restoration	Unnamed tributary to Third Fork Creek that flows into Third Fork Creek just downstream (south) of S. Roxboro Street in Hope Valley Farms subdivision. Legacy project ID 231.	$848,106
Buffer Restoration				**Total: $3,363,811**
1	137	Buffer Restoration	Unnamed tributary to Third Fork Creek on the western edge of Forest Hills Park upstream of 15-501 Business (University Drive) for approximately 1,550 feet. Legacy project ID 103.	$183,259
2	142	Buffer Restoration	Unnamed tributary of Rock Creek running from E. Lawson Street just west of S. Alston Avenue (Highway 55) under Dayton Street ending at Truman Street. Legacy project ID 118.	$227,971

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
3	144	Buffer Restoration	Rock Creek flowing down from S. Alston Avenue to Apex Highway (Highway 55). Legacy project ID 121.	$275,418
4	141	Buffer Restoration	Unnamed tributary to Rock Creek east of S. Alston Avenue (Highway 55) on northern edge of park (park name unknown) flowing for approximately 1,020 feet parallel to Sima Avenue and continuing under Ridgeway Avenue. Legacy project ID 117.	$162,322
5	135	Buffer Restoration	Unnamed tributary to Third Fork Creek on the eastern edge of Forest Hills Park downstream of E. Forest Hills Blvd. Legacy project ID 101p).	$175,850
6	164	Buffer Restoration	Unnamed tributary to Third Fork Creek on the western edge of Forest Hills Park downstream of W. Forest Hills Blvd. Legacy project ID 234.	$139,395
7	158	Buffer Restoration	Third Fork Creek downstream from the intersection of W. Lakewood Avenue and 15-501 Business (University Drive). Legacy project ID 208.	$429,245
8	155	Buffer Restoration	Unnamed tributary to Third Fork Creek downstream of the intersection of S. Roxboro Street and 15-501 Business (Lakewood Avenue). Legacy project ID 204.	$145,885
9	159	Buffer Restoration	Third Fork Creek on the northern edge of Forest Hills Park running under W. Enterprise Street. Legacy project ID 209.	$535,421
10	136	Buffer Restoration	Unnamed tributary to Third Fork Creek running through Lyon Park and Center from the north end of the park to W. Lakewood Avenue east of Kent Street. Legacy project ID 102.	$221,594
11	156	Buffer Restoration	Unnamed tributary to Third Fork Creek running parallel to and on the south side of 15-501 Business (W. Lakewood Avenue). Legacy project ID 205.	$113,371
12	145	Buffer Restoration	Rock Creek flowing downstream of the intersection of Dakota Street and Highway 55 for approximately 900 feet and west of Highway 55. Legacy project ID 122.	$222,469
13	139	Buffer Restoration	Unnamed tributary to Third Fork Creek flowing parallel to and on the north side of W. Cornwallis Road between University Drive and S. Roxboro Street downstream from Whitley Drive. Legacy project ID 107.	$205,020
14	153	Buffer Restoration	Third Fork Creek flowing downstream of Cobb Street toward 15-501 Business (W. Lakewood Avenue). Legacy project ID 201.	$173,594
15	154	Buffer Restoration	Third Fork Creek flowing from the downstream end of Buffer Restoration-14 for approximately 300 feet to 15-501 Business/W. Lakewood Avenue. Legacy project ID 202.	$152,997

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
Keystone Properties[3]				**Total: $11,714,904**
1	178	Keystone Property	Parcel ID #122367 along the eastern banks of Third Fork Creek between Barnhill Street (to the north) and Springdale Drive (to the south and east).	$392,258
2	268	Keystone Property	Parcel ID #196541 on both sides of Third Fork Creek spanning from the corner of S. Roxboro Street and Martin Luther King, Jr. Blvd. west to the Creek.	$30,352
3	240	Keystone Property	Parcel ID #146335 along the eastern banks of Third Fork Creek between the new Walmart located at S. Roxboro Street and Martin Luther King, Jr. Blvd. (to the east) and Durham County's Maintenance facility accessed off of Martin Luther King, Jr. Blvd. (to the west).	$293,965
4	218	Keystone Property	Parcel ID #135307 just downstream of Historic Hope Valley south of Willow Bridge Drive. A sanitary sewer easement runs through this parcel.	$2,444,232
5	237	Keystone Property	Parcel ID #145481 along the eastern banks of Third Fork Creek between Carlton Crossing Drive (to the east) and Oriole Drive (to the west).	$717,899
6	210	Keystone Property	Parcel ID #135103 along the western banks of Third Fork Creek east of Berwick Court just north of Keystone Unique ID 213.	$533,671
7	213	Keystone Property	Parcel ID #135177 along the western banks of Third Fork Creek east of Burnley Court just south of Keystone Unique ID 210.	$1,146,852
8	224	Keystone Property	Parcel ID #135498 on both sides of Third Fork Creek adjacent to and just north (upstream) of S. Roxboro Street in Hope Valley Farms subdivision.	$1,013,416
9	166	Keystone Property	Parcel ID #107193 located near the Faith Assembly Christian Academy off of Fayetteville Road between the southern terminus of Jubilee Lane and the northern terminus of Atlantic Street.	$63,411
10	227	Keystone Property	Parcel ID #135691 on both sides of Third Fork Creek just downstream of W. Woodcroft Parkway. This area includes the play fields just west of Woodcroft Swim and Tennis Club and forested lands behind Woodcroft Shopping Center.	$1,276,885
11	267	Keystone Property	Parcel ID #196540 just east of Keystone Unique IDs 210 and 213 and west of Brenmar Lane and Cherry Blossom Circle.	$386,609
12	238	Keystone Property	Parcel ID #145491 along the eastern banks of Third Fork Creek between Bridgewood Drive (to the east) and Willow Bridge Drive (to the west).	$819,561

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
13	223	Keystone Property	Parcel ID #135497 on both sides of Third Fork Creek adjacent to and just south (downstream) of S. Roxboro Street in Hope Valley Farms subdivision.	$1,214,678
14	269	Keystone Property	Parcel ID #198505 just east of Keystone Unique ID 267 and west of S. Roxboro Street, north of Brenmar Lane.	$1,144,097
15	262	Keystone Property	Parcel ID #156681 in the headwaters of Rock Creek to the west of S. Briggs Avenue at the southern end of Person Street.	$237,018
Urban Gems[3]				**Total: $ 901,950**
1	359	Urban Gem	Parcel ID #133429 just west of the American Tobacco Trail and east of Hillside High School.	$20,725
2	357	Urban Gem	Parcel ID #133266 on the eastern side of Rock Creek just southwest of Elmira Avenue.	$160,530
3	325	Urban Gem	Parcel ID #116414 at the eastern end of Barton Street.	$5,332
4	329	Urban Gem	Parcel ID #117793 south of the eastern end of Truman Street and just north of URB-8 and Rock Creek.	$112,820
5	344	Urban Gem	Parcel ID #132851 on both sides of Rock Creek and north of Athens Avenue near Majestic Drive, just south of Urban Gem Unique ID 329.	$106,844
6	365	Urban Gem	Parcel ID #201990 east of Short Street and south Cecil Street, to the east of Urban Gem Unique ID 324.	$129,781
7	296	Urban Gem	Parcel ID #107729 near the intersection of James Street and Ward Street.	$24,900
8	294	Urban Gem	Parcel ID #107660 just north (upstream) of 15-501 Business where University Drive and 15-501 Business merge.	$57,460
9	362	Urban Gem	Parcel ID #146794 just north and west of Cook Road where Brown Street and Cook Road intersect.	$66,942
10	328	Urban Gem	Parcel ID #117212 near the eastern end of Moline Street to the south and north of Bell Street just east of C.C. Spaulding Elementary School.	$48,135
11	356	Urban Gem	Parcel ID #133264 between the southern end of Hemlock Avenue where it ends at Elmira Avenue and McLaurin Avenue adjacent and to the west of URB-9.	$47,408
12	358	Urban Gem	Parcel ID #133371 just southwest of Elmira Avenue just east of Urban Gem Unique ID 355 at the northern end of Curtis Street.	$42,838

Map ID[1]	Unique ID[2]	Type	Description	20-Year Life Cycle Cost
13	355	Urban Gem	Parcel ID #133263 between the southern end of Hemlock Avenue where it ends at Elmira Avenue and McLaurin Avenue adjacent and to the east of Urban Gem Unique ID 356.	$41,909
14	324	Urban Gem	Parcel ID #116095 east of E. Alton Street and south of Short Street directly west of Urban Gem Unique ID 365.	$33,698
15	323	Urban Gem	Parcel ID #116094 east of E. Alton Street and south of Short Street directly west of Urban Gem Unique ID 324.	$2,628

[1] MAP ID refers to the label used to identify high priority projects in Figure 6.
[2] Unique ID refers to a project specific numbering system implemented following the initial identification of watershed opportunities which were previously assigned as project ID (i.e., SCM or Reach ID) or parcel ID for preservation projects. The Unique ID numbering system spans across project type and is always a three digit number.
[3] Some keystone properties and urban gems may currently be subject to voluntary protection by existing homeowner's association covenants.

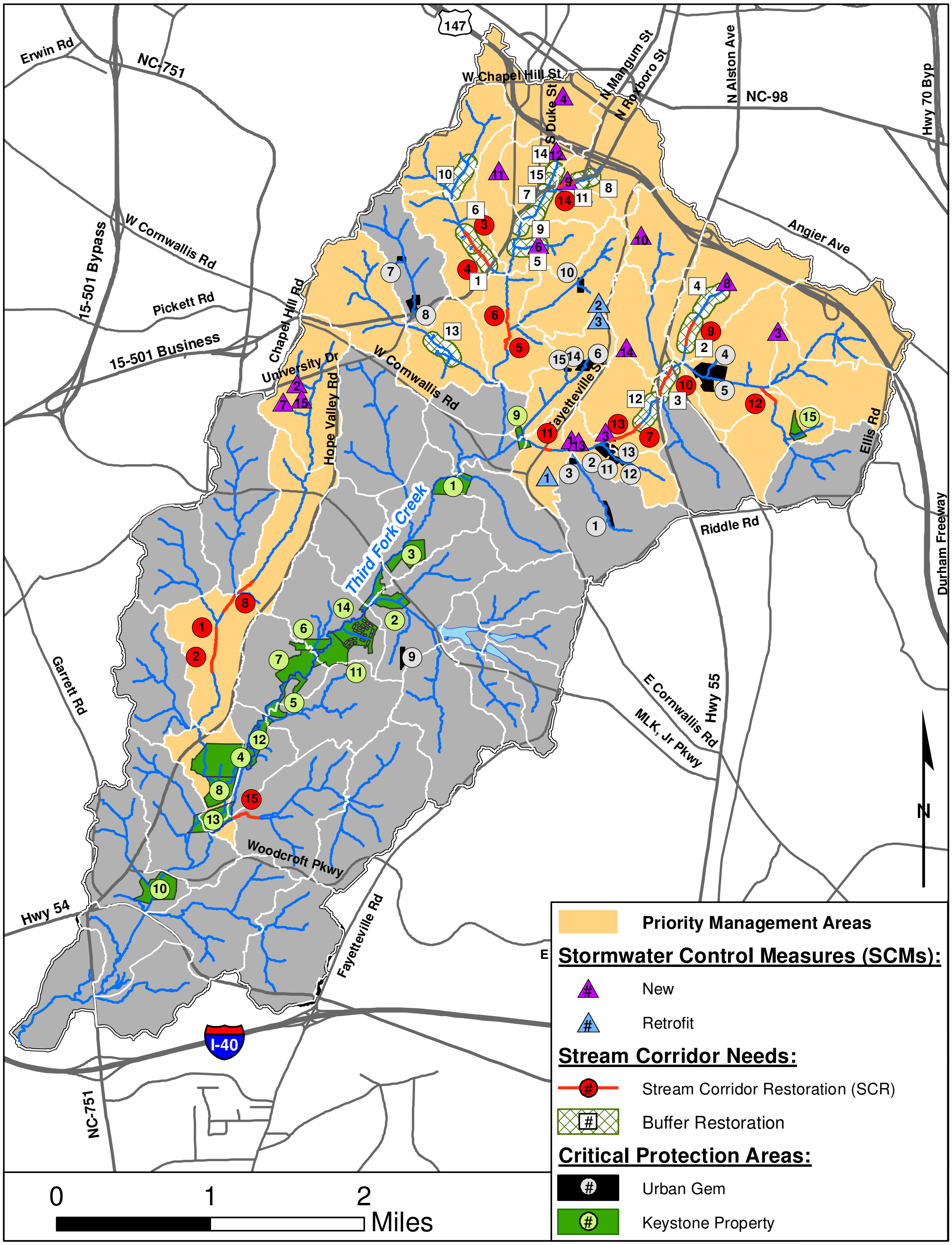

Figure 6. Location of Recommended High-Priority Sites and Practices (Refer to Table 1 for corresponding list of Map IDs)

Other Recommended Watershed Improvement Actions

Existing management activities were reviewed to identify and highlight those critical to addressing the pollutants of concern and those able to achieve multiple objectives and benefits for the community. Opportunities to strengthen or enhance existing public education, outreach, and participation efforts were identified. Finally, City programs and ordinance codes that affect water quality were evaluated for potential improvement opportunities.

The following changes to current public outreach, education, and participation efforts are considered to be priority recommendations:

- Improve education efforts regarding the benefits of stream buffers, no-mow areas, and buffer replanting. Recommend focusing initial efforts in those areas identified for high-priority stream restoration projects.
- Evaluate opportunities to expand the installation of rain gardens, downspout disconnections, and cisterns in order to redirect runoff from impervious surfaces onto vegetated areas. Actively recruit homeowners in the high-priority areas that are willing to implement these practices.
- Prioritize stream cleanup efforts in those areas identified for high-priority stream restoration projects or where problem areas were observed by field crews.
- Enhance outreach to professional lawn and turf maintenance providers. Develop educational materials and programming about proper fertilizer use and rates of application, the benefits of vegetated buffers, and the importance of revegetating bare or actively eroding areas.

The following changes to existing City codes and manuals are recommended:

- Develop and pursue approval of Triassic Basin-specific standards for SCMs that are limited by soil infiltration capacity. Such standards will likely vary from DWQ’s current generic standards and will provide for optimized performance under local conditions.
- After new State permeable pavement chapter is added to the state BMP manual, revise or incorporate the chapter into the City’s permeable pavement design standards to better suit Durham’s hydrologic and soil conditions.
- Finalize SCM design standards in Durham’s Reference Guide for Development (RGD) regarding allowance of bioretention with internal water storage in C and D soils with conditions (in coordination with NCSU and NCDENR).
- Revise the RGD to require use of the *raked method* for constructing the bioretention bottom surface.
- Consider alternative reduced street widths, such as 20 feet for Residential Limited and Residential Street and 26 feet for Residential Local Street (with on-street parking, one lane).

- Revise street cross-sections, or provide cross-section alternatives, to include water quality treatment devices.
- Finalize guidance in the RGD on the proper application, configuration, and uses of rainwater harvest/cisterns.

Implementation

The WMP recommends key actions to take in the coming decade. The City's Stormwater Services Division will take the lead in carrying out most of these actions with support from other City departments, as well as citizens, other agencies and organizations. The ability to implement the recommendations of this WMP will depend on many factors, including available funding and resources, water quality regulatory requirements, and other priorities identified by the community. The WMP should be viewed as a starting point to help guide the City towards the goal of improved water quality in Third Fork Creek and compliance with state and federal regulations.

The WMP recommends using tracking indicators to monitor changes in watershed conditions and to measure how well the watershed goals and objectives are being achieved over time. These tracking indicators include both science-based measurements (e.g., pollutant concentrations) and programmatic information (e.g., area treated with SCMs, length of stream restored, and area of open space protected). The City will periodically review key actions and revise them as new information becomes available, experience is gained, and success is achieved.

In order to help identify and plan for costs associated with the recommendations made in the WMP for priority projects, the following cost-benefit analysis has been prepared. The analysis considers the total implementation cost by combining the engineering and design, land acquisition, construction, and 20-year operations and maintenance costs (see results in Table 2 through Table 7 below). Note that this analysis only considers structural SCMs, stream and buffer restoration/enhancement projects, and preservation of urban gems and keystone properties. It does not include the costs associated with the recommendations made for enhancing or maintaining existing water quality improvement programs such as public education, ordinance codes changes, or suggested good housekeeping and SCM maintenance measures for municipal operations. In addition, the SCM and stream and buffer restoration costs are based on site specific cost estimates developed using limited site information and configuration assumptions. In addition, the sites were limited to opportunities identified during field screening. As a result, the costs may not be fully representative of costs for implementation throughout the watershed and may vary from costs reported by other sources.

Table 2. Top 15 New Structural SCM Opportunities - Estimated Cost and Benefits

Total Implementation Cost	$3,581,396
Estimated Benefits in Load Reduction	258 lbs/yr TN 15 lbs/yr TP 5,105 lbs/yr TSS
Median Cost Per Pound of Pollutant Removed Per Site	$17,467/lb/yr TN reduced $440,949/lb/yr TP reduced $1,241/lb/yr TSS reduced

Total cost includes engineering and design, land acquisition, construction, and 20-year O&M. See Section 6.2.1.1 of the WMP for more detail. *TN – Total Nitrogen; TP – Total Phosphorus; TSS – Total Suspended Solids*

Table 3. Top 3 SCM Retrofit Opportunities - Estimated Cost and Benefits

Total Implementation Cost	$316,494
Estimated Benefits in Load Reduction	11 lbs/yr TN 1.1 lbs/yr TP 405 lbs/yr TSS
Median Cost Per Pound of Pollutant Removed Per Site	$23,285/lb/yr TN reduced $474,015/lb/yr TP reduced $932/lb/yr TSS reduced

Total cost includes engineering and design, land acquisition, construction, and 20-year O&M. See Section 6.2.1.1 of the WMP for more detail. *TN – Total Nitrogen; TP – Total Phosphorus; TSS – Total Suspended Solids*

Table 4. Top 15 Stream Restoration/Enhancement Opportunities - Estimated Cost and Benefits

Estimated Implementation Cost	$9,857,160
Estimated Benefits in Load Reduction	248 lbs/yr TN 43 lbs/yr TP 1,623,682 lbs/yr TSS
Median Cost Per Pound of Pollutant Removed Per Site	$39,482/lb/yr TN reduced $225,560/lb/yr TP reduced $8/lb/yr TSS reduced

Total cost includes engineering and design, land acquisition, construction, and 20-year O&M. See Section 6.2.1.1 of the WMP for more detail. *TN – Total Nitrogen; TP – Total Phosphorus; TSS – Total Suspended Solids*

Table 5. Top 15 Buffer Restoration/Enhancement Opportunities - Estimated Cost and Benefits

Total Implementation Cost	$3,363,811
Estimated Benefits in Load Reduction	125 lbs/yr TN 10 lbs/yr TP 4,632 lbs/yr TSS
Median Cost Per Pound of Pollutant Removed Per Site	$1,531/lb/yr TN reduced $18,875/lb/yr TP reduced $41/lb/yr TSS reduced

Total cost includes engineering and design, land acquisition, construction, and 20-year O&M. See Section 6.2.1.1 of the WMP for more detail. *TN – Total Nitrogen; TP – Total Phosphorus; TSS – Total Suspended Solids*

Table 6. Top 15 Urban Gem Site Opportunities - Estimated Cost and Benefits

Total Implementation Cost	$901,950
Estimated Benefits in Load Reduction	See note below

Total implementation cost includes land acquisition for the entire parcel and 20-year O & M. See Section 6.2.1.1 of the WMP for more detail.
Benefits are dependent on site zoning. No approved accounting method is available. A suggested way to calculate benefits is as follows. For each parcel targeted for acquisition, pollutant loading prevention can be estimated by matching the current zoning of the property to the appropriate land use category in Table 12. Multiply the acres by the loading (e.g., TN lb/ac/yr) for both the zoned land use and the preserved open space for the area of the property that otherwise could have been developed. The difference between the two annual loads is the load avoidance benefit from preservation.

Table 7. Top 15 Keystone Property Opportunities - Estimated Cost and Benefits

Total Implementation Cost	$11,714,904
Estimated Benefits in Load Reduction	See note below

Total implementation cost includes land acquisition for the entire parcel and 20-year O & M. See Section 6.2.1.1 of the WMP for more detail.
Benefits are dependent on site zoning. No approved accounting method is available. A suggested way to calculate benefits is as follows. For each parcel targeted for acquisition, pollutant loading prevention can be estimated by matching the current zoning of the property to the appropriate land use category in Table 12. Multiply the acres by the loading (e.g., TN lb/ac/yr) for both the zoned land use and the preserved open space for the area of the property that otherwise could have been developed. The difference between the two annual loads is the load avoidance benefit from preservation.